

*CONTRAST AND REALLOCATION OF
EXTRANEOUS REINFORCERS BETWEEN
MULTIPLE-SCHEDULE COMPONENTS*

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Four pigeons responded in components of multiple schedules in which two responses were available and reinforced with food. Pecks on the left key ("main" key) were reinforced at a constant rate in one component and at a rate that varied over conditions in the other component. When reinforcer rate was varied, behavioral contrast occurred in the constant component. On the right key ("extra" key), five variable-interval schedules and one variable-ratio schedule, presented conjointly, arranged reinforcers for responses in all conditions. These conjoint schedules were common to both multiple-schedule components—rather than unique to particular components—and reinforcers from these schedules could therefore be arranged in one component and obtained during the other component. In this way, the additional reinforcers were analogous to the "extraneous" reinforcers thought to maintain behavior other than pecking in conventional multiple schedules. Response rate on the extra key did not change systematically over conditions in the constant component, and in the varied component extra responding was inversely related to main-key reinforcement. All subjects obtained more extra-key reinforcers in whichever component arranged fewer main-key reinforcers. Consistent with the theory that reallocation of extraneous reinforcers may cause behavioral contrast, absolute reinforcer rate for the extra key in the constant component was low in conditions that produced positive contrast on the main key and high in those that produced negative contrast. Also consistent with this theory, behavioral contrast was reduced in two conditions that canceled extra-key reinforcers that had been arranged but not obtained at the end of components. Thus, a constraint on reallocation markedly reduced the extent of contrast.

Key words: extraneous reinforcers, reallocation, behavioral contrast, multiple schedules, key peck, pigeons

In multiple schedules, two component schedules are presented successively in an alternating sequence, and each component is accompanied by a distinctive stimulus. In steady-state performances, subjects often exhibit behavioral contrast when reinforcer rate is varied in one component over conditions in which the alternate component remains constant. Positive behavioral contrast, for example, is a response-rate increase in the constant component when reinforcer rate is reduced in the varied component; it occurs despite the fact that such increases in responding do not appreciably alter the obtained rate of reinforcers (Lander & Irwin, 1968; Reynolds, 1961). A

second contrast phenomenon, possibly related to behavioral contrast, is observed when patterns of responding are studied over the course of a component presentation. In a component rich in reinforcement, response rates at the beginning are often higher than at the end; early in a lean component, responding is lower than at the end (but see Buck, Rothstein, & Williams, 1975, for an exception). This phenomenon, *local contrast*, was first studied systematically by Nevin and Shettleworth (1966).

A good deal of research has attempted to determine what conditions affect the extent of behavioral contrast, and the focus of much of this work has been the manner in which the multiple schedules are arranged (for a review, see Williams, 1983). For example, studies have reported the effects of manipulating the time for which components are available on each presentation (McSweeney, 1982; Williams, 1979, 1981, 1989), the rate of reinforcement in the constant component (Dougan, McSweeney, & Farmer, 1985; McSweeney, Dougan, Higa, & Farmer, 1986; Nevin, 1974;

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Reynolds, 1963), or the magnitude of the reinforcers used in the constant component (Harper & McLean, 1992; Nevin, 1974).

Current theories about behavioral contrast can be divided into main categories: those that assume an additional behavioral process mediating the effects of reinforcement in a temporally distant component and those that assume that components of multiple schedules interact in that reinforcers from both components directly influence responding in either component (e.g., Herrnstein, 1970). A recent version of this direct interaction is Williams' (1983) view that contrast is anticipatory in nature (see also Williams & Wixted, 1986). That is, responding is low in a component that is followed by a high rate of reinforcement and is high in one that is followed by a low rate. The alternative view of contrast is often called the "reallocation" hypothesis. Like Herrnstein's analysis, this view assumes that the schedule maintaining responding in a component competes with another schedule of "extraneous" reinforcers. Extraneous reinforcers are hypothetical events that are thought to be produced by subjects engaging in behavior other than the response under study (e.g., actions such as grooming and resting) and are not directly controllable by the experimenter. These reinforcers were proposed by Herrnstein (1970, 1974), who argued that their existence is required by the logic of the matching law. Unlike Herrnstein's analysis, the reallocation view is that contrast occurs when these extraneous reinforcers, which are available throughout experimental sessions, are "reallocated" between components by the subject, thereby changing the conditions of competition between the schedule arranged by the experimenter and extraneous reinforcement (e.g., McLean, 1988, 1991; McLean & White, 1983; Staddon, 1982). For example, the increase in constant-component responding that occurs when extinction is introduced in the alternate component does so, according to this theory, because some extraneous reinforcers are reallocated from the constant component to the extinction component, and there is thus a decrease in extraneous reinforcer availability in the constant component. Because responding is known to be inversely related to the rate of concurrently available reinforcement (Catania, 1963; Rachlin & Baum, 1972), this reduction in extraneous reinforcement in the

constant component increases responding. Thus, even for a component in which the schedule remains constant over experimental conditions, there may be changes to the context of concurrent reinforcement for responding; these changes are thought to be critical determinants of behavioral contrast. A similar account may be advanced for local contrast (see Staddon, 1982), although McLean (1991) has shown that local contrast can occur independently of possible reallocation of reinforcers.

Direct interaction theories require interaction of reinforcement schedules that are temporally distant from one another, because of the successive arrangement of multiple-schedule components. One reason the reallocation hypothesis is attractive is because it attributes changes in behavior to changes in the simultaneously present context for responding—specifically, changes in concurrent sources of reinforcement (Catania, 1963). However, for contrast to be explained in this way, reallocation must have at least two particular features. First, reallocation must involve changes in the absolute rate of extraneous reinforcement during the constant component. It is not sufficient for the distribution of extraneous reinforcers between the two components to vary over conditions, because this may occur without changes in the rate of extraneous reinforcers in the constant component. Second, reallocation must result from changes in reinforcement in the varied component and not from changes in behavior during the constant one. If reallocation relied on behavior change in the constant component, then it would be logically circular to claim that reallocation produces behavior change in that component. Thus, if it is to account for contrast, reallocation needs to be a change in the absolute rate of extraneous reinforcement in the constant component produced by events during the varied component.

One major and rather obvious difficulty for development of the reallocation theory of contrast is that extraneous reinforcers are not measured; thus, the hypothetical process of reallocation is invisible. However, behavior thought to be maintained by extraneous reinforcers has been studied (see Dougan et al., 1985; Dougan, McSweeney, & Farmer-Dougan, 1986; Hinson & Staddon, 1978; Rand, 1977), and the reallocation theory is consistent with quantitative statements about the deter-

minants of behavior in conditions in which several sources of reinforcement are available simultaneously (e.g., Catania, 1963; Rachlin & Baum, 1972). Still, the difficulty of measuring extraneous reinforcers directly has meant that there has not yet been a convincing demonstration of reinforcer reallocation.

It may be possible to measure the process of reallocation using an experimental analogue of extraneous reinforcement. McLean and White (1983) proposed a characterization of multiple-schedule performance that predicts stronger discrimination between components (i.e., larger differentials between response rates across components) when a large amount of extraneous reinforcement is available throughout experimental sessions. To test this prediction, McLean and White arranged schedules that were similar to multiple schedules except that two key-peck responses were available during each component instead of only one. A conventional multiple schedule was arranged on one (the main key), and an alternative source of reinforcement, analogous to extraneous reinforcement, was provided by the second key. Reinforcers for this extra response were arranged according to variable-interval schedules and were added to the extraneous reinforcement context for responding on the main key. Thus, whereas conventional schedule arrangements do not permit direct control of extraneous reinforcement, explicitly arranged analogues of these reinforcers are controllable; in this way, the total extraneous reinforcement (i.e., all reinforcers other than those for responding on the main key) was largely under experimental control. This enabled two experiments that confirmed predictions from their model. In one experiment, analogue extraneous reinforcement was arranged at either high or low equal rates in the two components. This variation of the overall rate of extraneous reinforcement produced stronger discrimination when the rate was high than when it was low. In the second experiment, the schedules used for the extra response were unequal across the two components and produced response bias on the main key favoring the component with a lower rate of extraneous reinforcement. Thus, as McLean and White argued, explicit alternative reinforcement was a useful analogue in demonstrating behavioral processes involving extraneous reinforcement in multiple schedules.

The problem of measuring extraneous reinforcement for the reallocation model of contrast can be overcome by adopting a similar strategy. If explicitly programmed reinforcers were available for a second response and were scheduled in a way that allows subjects to reallocate them between components, then reallocation (if it is a robust phenomenon) might very reasonably be expected. However, data from McLean and White's (1983) study are not appropriate for this purpose, because they used independent schedules for their analogue during each component. Independent schedules arrange reinforcers that can be obtained only during their respective components and cannot be redistributed between components. Other studies have arranged a single extra-key schedule that operated during both components rather than independent extra-key schedules for the two components (Lobb & Davison, 1977; Pliskoff, Shull, & Gollub, 1968). However, these studies were concerned with discriminative performance rather than behavioral contrast and did not arrange multiple-schedule conditions that could be used to study contrast.

The present work arranged multiple schedules on a main key in which reinforcer rate was constant in one component and was varied over conditions in another component. On an extra key, a second response was reinforced concurrently according to a schedule that, like Lobb and Davison's (1977), was common to both of the two multiple-schedule components. For comparison, some of these conditions were also conducted with reallocation constrained. The constraint was imposed by canceling extra-key reinforcers that had been arranged but not obtained by the end of a component. At issue is whether, given no constraint on when the reinforcers from this second schedule can be obtained, subjects will vary the rate of these reinforcers in both components.

METHOD

Subjects

Four homing pigeons were maintained at 80 to 85% of free-feeding body weights. All had previous training in conditions similar to those used in the present study. Water and grit were continuously available in home cages, where supplementary feed of mixed grain was

given shortly after experimental sessions to help maintain prescribed weights.

Apparatus

Four similar experimental chambers (34 cm by 34 cm by 32 cm) each contained an interface panel with three response keys, one mounted centrally and the others 9 cm to either side of it, all 21 cm above the grid floor. On either of the side keys, pecks that exceeded approximately 0.15 N produced a relay click and turned off (for 50 ms) the red or green lights illuminating the key from behind. A hopper containing wheat was mounted in the center of the interface panel 6 cm above the floor and was operated and lit with white light during reinforcement. The center key and the house-light were not used. Scheduling and recording of all experimental events were accomplished with an IBM-AT® compatible computer running MED-PC® software.

Procedure

Experimental sessions lasted 40 min and were normally conducted 7 days per week. Responses on the left ("main") key were reinforced according to a two-component multiple variable-interval (VI) VI schedule, with 3-s access to wheat as the reinforcers. Components alternated strictly at intervals of 40 s and were signaled by red or green light on the response key. Reinforcers arranged but not obtained by the end of a component were never canceled and could be obtained the next time the component was presented. The VI schedules were constructed using 12 intervals from Fleshler and Hoffman's (1962) progression, which were sampled at random without replacement until all 12 had been used before any was reused. Separate schedules were always used for the two components. A VI 50-s schedule was always used in one component; the schedule used in the other component was varied over conditions.

The same discriminative stimuli were also present on the right ("extra") key. The contingencies arranged for this key were designed to imitate the way in which alternative activities might produce extraneous reinforcers. A variety of activities presumably produces extraneous reinforcers (scratching, pacing, resting, etc.) so that an appropriate analogue will make reinforcers available as if from a variety of sources. Some portion of these will be delivered on a ratio basis (see Pear, 1975) but

many will surely occur on an interval basis. For example, resting will be reinforced at some times but not at others, depending on the onset of fatigue. In other cases, more complex combinations of ratio and interval schedules might govern reinforcer availability. For example, repetitive grooming or scratching may produce reinforcement on a ratio basis, but opportunities for such reinforcement may arise at irregular intervals when skin irritation signals that it is available. For these reasons, a variety of schedules all arranged reinforcers for this extra key. Responses were maintained by five separate VI 100-s schedules, running simultaneously, and one variable-ratio (VR) 425 schedule. Unlike the VI schedules on the main key, these extra schedules operated during presentations of both components; that is, independent schedules were not used for each multiple-schedule component on this key as they were for the main key. Therefore, if an extra schedule timed out during one component but no extra-key response occurred, the reinforcer could be obtained during the alternated component. A response on the extra key produced a reinforcer if any of the VI schedules had timed out and counted towards the VR schedule only if none had timed out. As usual, when an interval of a VI schedule timed out, that schedule stopped until the reinforcer was delivered. If several had timed out, then as many successive responses would all produce reinforcers and each would restart one of the timed-out VI schedules. One of the five extra-key VI schedules was intended to imitate the contingency on grooming described above. In this case, reinforcer availability occurred at irregular intervals according to the VI and was signaled by a white light on the extra key. Once the signal for this reinforcer was presented, extra-key responses counted only towards this contingency. Completion of five responses was then required for delivery of a 3-s reinforcer and removal of the white stimulus. For the remaining schedules, reinforcers for extra-key responses varied unpredictably between 1-s and 2-s duration.

For some conditions, a constraint was imposed such that reinforcers that became available for extra-key responding during a component were canceled if they were not obtained by the time components alternated (constraint on reallocation); for the remaining conditions, reinforcers from these schedules remained available, regardless of which component was

in effect, until obtained (no constraint on reallocation). In all conditions, a changeover delay of 3 s prevented immediate reinforcement of a response that directly followed a response on the other key (changeover) or of any response within 3 s of any changeover. Training in each of the experimental conditions continued for at least 30 sessions, after which conditions were changed at the experimenter's convenience. This was adopted because in the author's experience, average performance does not change after this many sessions of training, although daily fluctuations may result in failure of conventional stability criteria. The influence of daily fluctuations in responding was minimized by taking data from the last 10, rather than five, consecutive sessions in a condition.

Before the series described here began, the 4 subjects had all served in a pilot experiment using the procedure described above. Thus, they were introduced directly into the first condition. The schedules used for the main key in each condition are given in Table 1, listed in the order in which they were presented to subjects. Table 1 also gives the conditions in which the constraint on reallocation described above was imposed and the number of sessions in each condition.

RESULTS

The main measures of interest are the absolute rates of reinforcers and responses on the extra key in the two components. Responses per minute (corrected for reinforcement time) and obtained reinforcers per hour for each key in each component are given in Table 2. Response and reinforcer rates for each of the final 10 sessions in each condition were calculated and averaged, and the standard deviations of response rates (see Table 2) indicate the stability of responding over these sessions. The mean response and reinforcer rates are the subject of the analyses below.

The major manipulation involved changes in main-key reinforcement in the varied component. The first question to be addressed has to do with the way in which reinforcers from the extra-key schedules were distributed between components, and how this distribution varied with main-key reinforcers in the varied component. In order for reallocation to be a plausible theory of contrast, it needs to be shown that extra-key reinforcers are not distributed

Table 1

Reinforcement schedule conditions for the main key in the constant and varied component, listed in the order in which they were run. Numbers of training sessions given in each condition are also shown. Reinforcement contingencies on the extra key were constant throughout the experiment and are described in the text. "Constraint" refers to conditions in which reinforcers arranged but not obtained for the extra key were canceled at the end of components.

Condition	Component		Constraint	Sessions
	Constant	Varied		
1	VI 50 s	VI 20 s	yes	34
2	VI 50 s	Ext	yes	36
3	VI 50 s	Ext	no	33
4	VI 50 s	VI 20 s	no	32
5	VI 50 s	VI 200 s	no	36
6	VI 50 s	VI 30 s	no	35
7	VI 50 s	VI 120 s	no	34

equally between components and that the distribution varies with main-key reinforcement. Moreover, it must be shown that these changes are not restricted to the varied component alone—extra-key reinforcer rate in the constant component must also vary across conditions. This is because the reallocation process needs to produce changes in the reinforcement context for responding in the constant component of the multiple schedule; otherwise, reallocation cannot serve as an account of behavior change in that component.

Figure 1 gives reinforcers per hour for the extra key in both components, plotted as a function of obtained reinforcers per hour for the main key during the varied component. (Reinforcer rates in the constant component are shown by open circles and those in the varied component are given by filled circles.) Across conditions, the distribution of reallocable extra-key reinforcers between components was clearly a function of the main-key reinforcer rate in the varied component. For the component of particular interest, the constant component, absolute reinforcer rates on the extra key show clear positive relations with main-key reinforcement for each subject. This indicates that subjects obtained fewer extra-key reinforcers in this component when it was richer than the varied one (e.g., in multiple VI 50 s VI 200 s) than they did when it was leaner than the varied component (e.g., in multiple VI 50 s VI 20 s). Thus the "constant" component of a multiple schedule, traditionally used to assess contrast effects, was constant

Table 2

Responses per minute and reinforcers per hour on main (left) and extra (right) keys for the constant component and the varied component. Rates were calculated for each of the last 10 sessions in each condition, taking account of time occupied by reinforcement in each component. The rates listed for each condition are means of the 10 daily rates, with standard deviations in parentheses. Results are listed in the order in which subjects were exposed to conditions (see Table 1).

Subject	Constant component						Varied component					
	Responses			Reinforcers			Responses			Reinforcers		
	Main	Extra		Main	Extra		Main	Extra		Main	Extra	
D5	31.7 (3.29)	24.17 (5.03)		62.21 (4.39)	89.11 (14.06)		52.85 (5.44)	18.45 (3.90)		158.35 (7.39)	97.74 (15.51)	
	49.77 (10.68)	29.61 (3.41)		67.43 (5.51)	89.84 (13.25)		4.09 (2.76)	61.42 (7.11)		0	108.59 (16.15)	
	59.02 (10.43)	20.2 (4.33)		67.27 (7.15)	60.11 (8.72)		2.66 (1.77)	68.78 (8.20)		0	117.78 (8.28)	
	36.62 (3.29)	24.04 (2.14)		61.03 (5.88)	108.88 (13.22)		58.78 (2.98)	9.01 (2.04)		166.74 (4.64)	58.78 (11.54)	
	54.86 (2.93)	16.3 (3.11)		63.09 (6.46)	70.27 (4.82)		20.57 (5.14)	55.6 (8.51)		16.25 (6.2)	102.81 (20.40)	
D6	36.97 (4.01)	26.6 (2.47)		64.02 (4.12)	104.63 (9.22)		59.87 (5.03)	13.5 (3.24)		109.01 (4.44)	68.67 (9.47)	
	58.36 (3.93)	16.65 (3.19)		67.07 (5.32)	65.78 (9.11)		30.53 (5.3)	46.31 (6.99)		25.32 (6.03)	104.75 (8.33)	
	49.12 (8.62)	19.31 (4.18)		62.59 (5.53)	102.98 (24.96)		78.7 (7.02)	8.62 (2.01)		153.35 (10.27)	81.03 (30.2)	
	47.81 (15.18)	19.35 (5.78)		52.45 (13.06)	120.99 (22.95)		8.88 (4.07)	39.23 (10.85)		0	108.03 (22.63)	
	80.04 (4.9)	9.64 (2.36)		64.61 (4.96)	38.93 (9.92)		10.14 (6.04)	60.14 (3.01)		0	134.21 (12.73)	
D7	52.25 (2.67)	11.78 (2.2)		67.14 (7.48)	90.9 (16.28)		71.24 (1.68)	5.28 (1.53)		166.56 (5.24)	50.9 (9.22)	
	63.97 (3.42)	5.66 (1.37)		68.06 (4.11)	41.3 (6.73)		21.49 (5.09)	34.46 (6.75)		15.72 (6.58)	122.39 (12.8)	
	56.12 (3.83)	15.25 (1.91)		66.66 (5.51)	87.4 (15.76)		62.98 (3.62)	11.47 (2.46)		109.2 (5.49)	72.85 (14.65)	
	62.33 (6.43)	7.57 (2.07)		65.09 (5.04)	43.85 (10.44)		24.27 (5.78)	31.24 (4.5)		22.88 (4.44)	123.09 (12.32)	
	67.89 (8.36)	9.9 (3.81)		67.23 (4.26)	83.41 (18.62)		111.71 (10.08)	3.08 (1.62)		164.06 (10.01)	54.08 (18.24)	
D8	74.81 (22.01)	10.91 (3.88)		60.10 (12.52)	94.54 (34.7)		11.94 (6.23)	45.3 (22.99)		0	86.89 (27)	
	90.15 (13.08)	6.66 (1.72)		67.6 (4.43)	36.77 (13.46)		5.91 (6.4)	52.28 (9.86)		0	134.9 (14.07)	
	49.59 (15.12)	7.94 (4.32)		63.01 (7.22)	76.8 (32.77)		92.41 (21.66)	4.9 (3.06)		160.6 (10.89)	43.38 (15.43)	
	92.92 (11.78)	7.39 (1.21)		66.9 (3.33)	48.24 (14.4)		35.48 (10.47)	30.22 (12.99)		14.64 (5.19)	112.03 (27.14)	
	70.7 (9.65)	6.22 (2.93)		69.5 (5.42)	77.18 (20.09)		112.71 (6.79)	3.35 (0.78)		113.58 (3.83)	57.14 (6.71)	
D8	63.42 (15.37)	6.55 (3.57)		62.16 (4.77)	61.03 (22.07)		43.38 (16.85)	9.59 (6.82)		24.55 (5.07)	65.16 (30.18)	
	56.33 (13.88)	30.42 (4.21)		63.97 (6.78)	114.27 (29.11)		88.05 (12.35)	13.39 (3.28)		155.02 (16.33)	97.31 (31.5)	
	61 (7.63)	40.15 (5.49)		63.04 (6.41)	146.72 (39.94)		8.57 (5.72)	40.13 (20.69)		0	74.21 (19.71)	
	78.98 (8.68)	26.99 (3.44)		67.78 (6.81)	65.88 (15.37)		7.28 (5.76)	65.92 (8.25)		0	111.21 (14.34)	
	54.4 (4.02)	38.1 (6.85)		65.45 (6.74)	118.61 (13.16)		121.63 (10.98)	7.02 (1.67)		167.03 (10.55)	51.61 (14.27)	
D8	73.75 (4.83)	16.38 (4.72)		67.83 (3.43)	56.56 (15.94)		30.27 (7.14)	49.79 (5.55)		14.08 (7.52)	115.23 (17.15)	
	60.68 (5.68)	26.29 (5.71)		68.26 (4.07)	106.82 (20.29)		112.68 (14.25)	9.66 (2.33)		111.21 (5.54)	53.32 (12.2)	
	73.19 (3.76)	6.87 (2.84)		67.90 (4.11)	47.58 (13.08)		47.7 (11.15)	37.39 (8.24)		27.41 (4.15)	115.77 (14.22)	

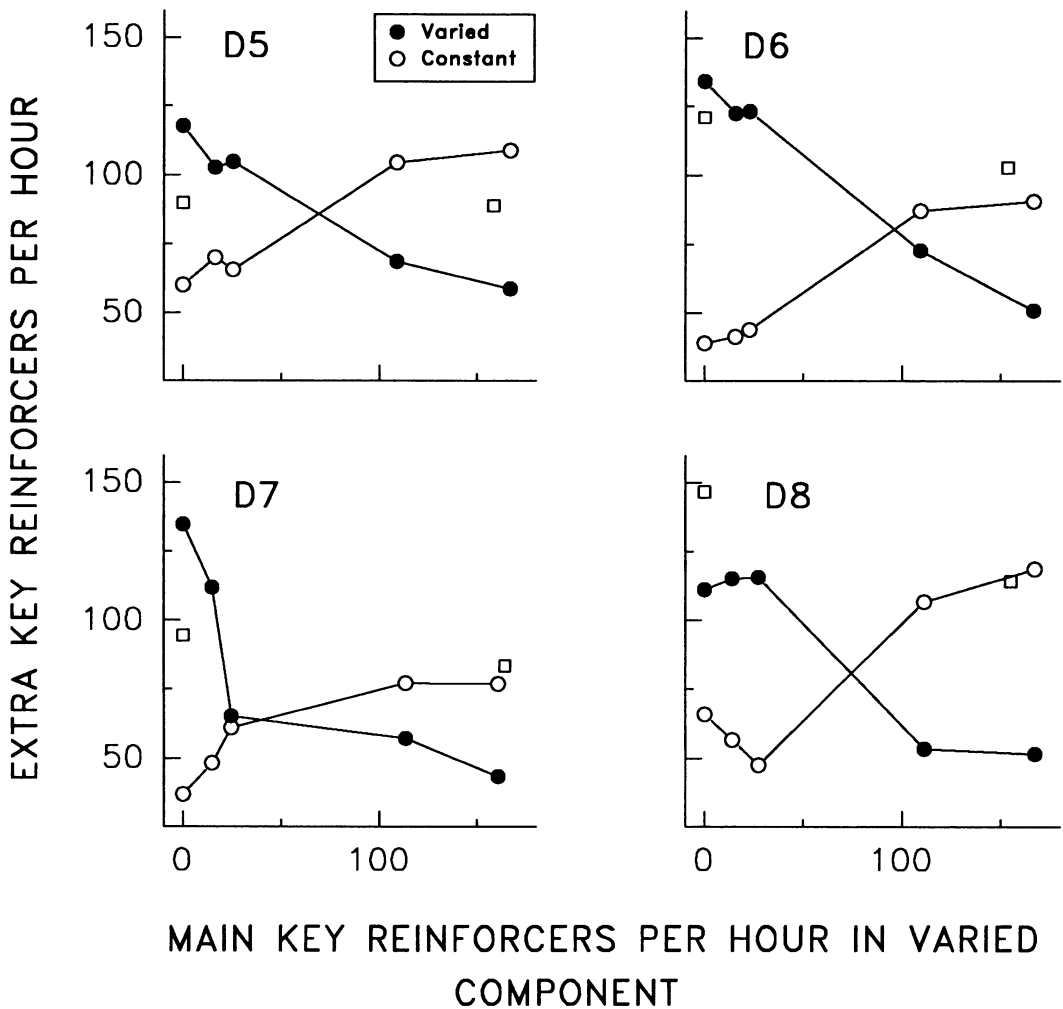


Fig. 1. Absolute rates of reinforcement from the extra key obtained in the constant (open circles) and varied (filled circles) components. Squares give data from the constant component in conditions in which reallocation was constrained by canceling extra-key reinforcers that were arranged but not obtained at the end of components. Reinforcer rates are plotted as a function of main-key reinforcers per hour obtained in the varied component.

only with respect to reinforcers arranged by the multiple schedule on the main key. The overall reinforcement context for this multiple-schedule component clearly was not constant at all. Squares in Figure 1 show extra-key reinforcer rates in the constant component for the two conditions in which there was a constraint on reallocation (imposed by canceling reinforcers arranged but not obtained by the end of a component). It is clear that for these conditions, extra-key reinforcer rates did not increase with increasing main-key reinforcement in the varied component.

Next, concern is with changes in response

rate and the question of whether subjects exhibited behavioral contrast in these conditions. Figure 2 gives absolute response rates on the main key in the constant component (open circles) and in the varied component (filled circles), plotted as a function of obtained reinforcer rate for the main key in the varied component. Squares in Figure 2 give response rates on the main key for conditions in which there was a constraint on reallocation of extra-key reinforcers. All subjects showed strong and quite clear behavioral contrast, in that response rate in the constant component decreased as reinforcer rate increased in the var-

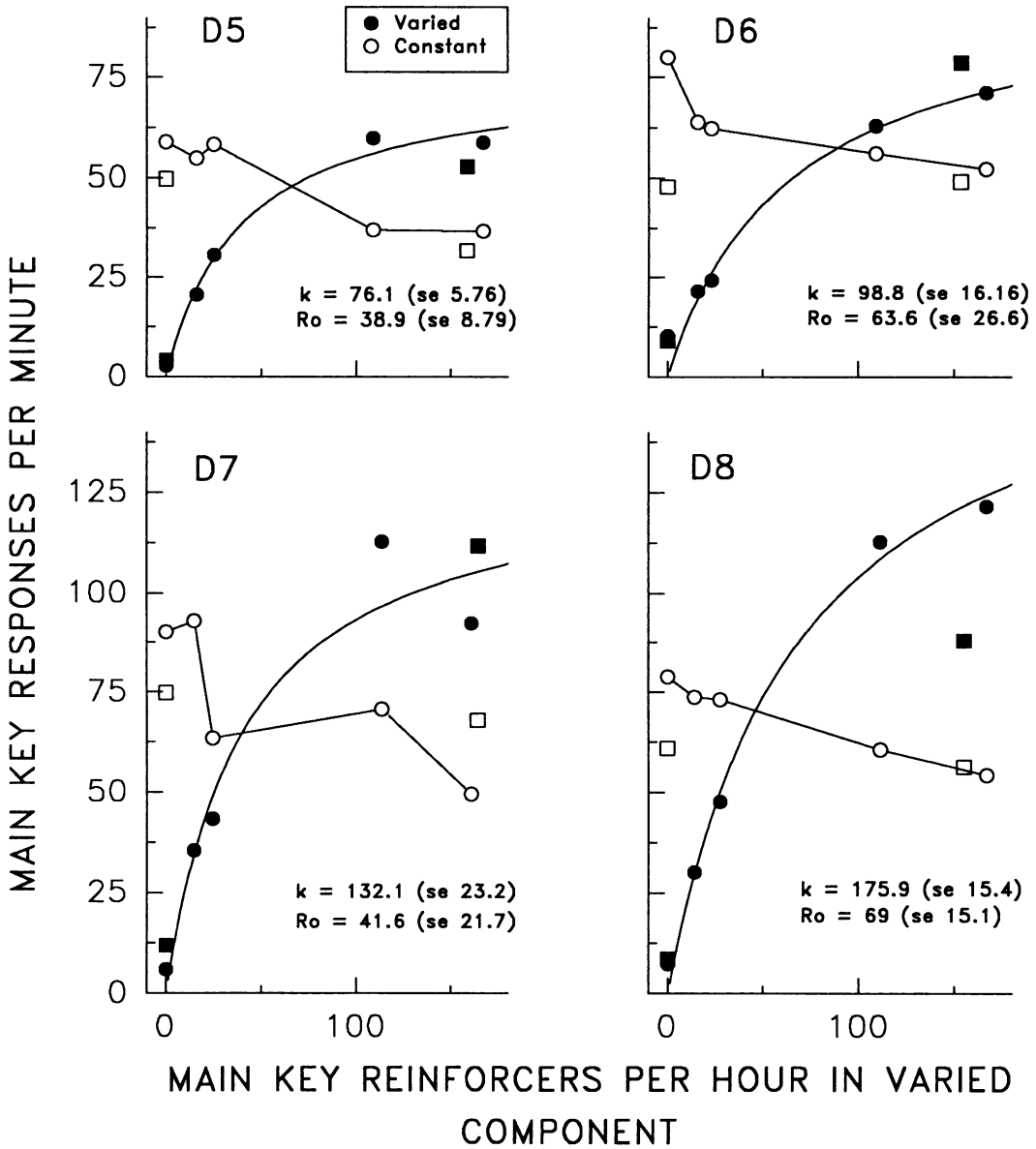


Fig. 2. Absolute rates of responding on the main key in the constant (open circles) and varied (filled circles) components, plotted as a function of main-key reinforcers per hour obtained in the varied component. Squares give constant-component data from conditions in which reallocation was constrained. For the varied component, data were fitted by Herrnstein's hyperbola; these curves are drawn on the figure. Estimates of the free parameters, with their standard errors, are given in each panel.

ied component. Comparing the extent of contrast shown in conditions with and without a constraint on reallocation of extra-key reinforcers, it is clear that there was less contrast when reallocation was constrained, although the difference was rather small for Bird D5 (compare the open circles with the open squares). Also for all subjects, response rates

and reinforcer rates in the varied component were strongly related (filled symbols). In conventional multiple schedules, this relation is known to be hyperbolic in form (Herrnstein, 1970). For this analysis, the following hyperbola was fitted to main-key data from conditions with no constraint on reallocation, using nonlinear regression analysis:

$$P_v = \frac{kR_v}{R_v + R_0}, \quad (1)$$

where P and R are response and reinforcer rates, respectively, and the subscript v identifies the component (here, the varied one) in which these events occur. The term k refers to the maximum response output a subject is capable of and depends on the topography of the response. Various interpretations of R_0 have been offered (see, e.g., Bradshaw, Szabadi, & Bevan, 1978), but the most common is that R_0 depends on reinforcement obtained in the same component from sources other than the schedule that arranges R_v .

The fitted hyperbolas are drawn in each panel of Figure 2 as descriptions of the behavior change. Estimates of the free parameters (k and R_0) and their standard errors are given for each subject. These hyperbolas fit the observed response rates well and account for more than 90% of the variance in each case. Thus the present data, as with data from conventional multiple schedules, conform to the hyperbolic function previously shown to relate reinforcer rate and response rate in a variety of schedule arrangements.

Figure 3 presents responses per minute over conditions for the extra key. Again, open circles give data from the constant component, and filled circles give data from the varied one. Squares give data from conditions with the constraint on reallocation. Large changes in extra-key responding occurred in the varied component when main-key reinforcement was manipulated. In the constant component, only small and unsystematic changes were observed. Comparison of Figure 3 with Figure 1 reveals some correspondence between extra-key response rate and extra-key reinforcer rate for the constant component (see especially Bird D8). Still, it is clear that the overall increase in reinforcer rate shown in Figure 1 is not present for response rate in Figure 3. Data from conditions with the constraint on reallocation were very similar to those from the remaining conditions.

DISCUSSION

The results of the present work confirm that when subjects respond on multiple schedules in a context in which alternative or extraneous reinforcers are also available, and the additional reinforcers are scheduled in a way that

allows them to be reallocated between components, subjects do indeed reallocate them. For all subjects, more of the reallocable extra-key reinforcers were obtained in components in which the main-key schedule was lean than in those in which the main-key reinforcement rate was high, and it was shown that this distribution of additional reinforcers could be manipulated by changing main-key reinforcement conditions in only one of the two components. Again for all subjects, it was shown that the changes in the distribution of additional reinforcers between components were accompanied by changes in the absolute rate of extra-key reinforcers during the constant component—that is, the relative change in the distribution of these reinforcers did not come about through changes in the varied component alone. It is important to note that the behavioral contrast that occurred on the main key in the constant component occurred in the context of a changing rate of alternative, extra-key reinforcement. In other conditions, however, reallocation of reinforcers between components was constrained by canceling extra-key reinforcers that had not been obtained by the end of components. This constraint eliminated reallocation of extra-key reinforcers, and contrast was reduced and unreliable across subjects.

These changes in extraneous reinforcement are consistent with the reallocation hypothesis for contrast in conventional multiple schedules in which there is no experimenter-arranged alternative to responding. If behavioral alternatives to the measured response exist even though none are explicitly arranged by the experimenter, and these actions are maintained by reinforcers that can be reallocated between components as has often been claimed, then the reallocation demonstrated in the present experiment seems likely to occur with these reinforcers as well. Thus, responding during the constant component occurs in the context of changing availability of extraneous reinforcement. According to the reallocation hypothesis, it is these changes to the reinforcement context for constant-component responding that bring about the phenomenon of contrast. The present findings confirm that reallocation may indeed contribute in the way proposed by this hypothesis.

The reallocation hypothesis is different from the view of contrast given in Herrnstein's (1970) formulation of the law of effect and in

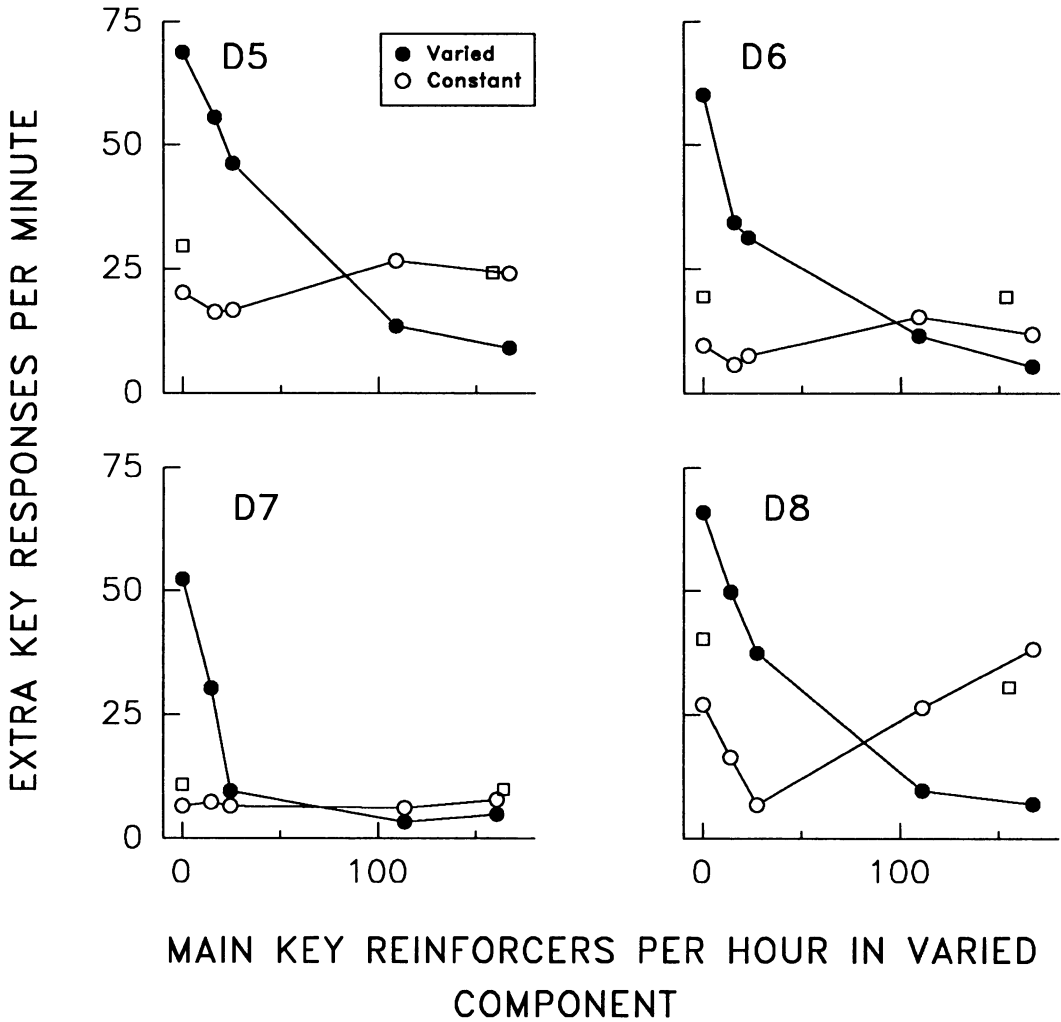


Fig. 3. Absolute rates of responding on the extra key in the constant (open circles) and varied (filled circles) components, plotted as a function of main-key reinforcers per hour obtained in the varied component. Squares give constant-component data from conditions in which reallocation was constrained.

the related form of Williams and Wixted (1986). Herrnstein's equation for the main-key response rate in the constant multiple-schedule component is

$$P_c = \frac{kR_c}{R_c + mR_v + R_e}, \tag{2}$$

in which R_e is extraneous reinforcers including those from the extra key. In the varied component,

$$P_v = \frac{kR_v}{R_v + mR_c + R_e}.$$

Because R_c is constant, this is identical to

Equation 1 ($R_0 = mR_c + R_e$). In Herrnstein's theory, contrast in the constant component is caused by changes in reinforcer rate over conditions in the varied component, and the term m is an interaction parameter that quantifies this effect of alternate-component reinforcement on response rate. However, this part of Herrnstein's theory has been questioned by several authors who have argued that for the model to be internally consistent, m must equal zero (see Davison & McCarthy, 1988; McLean & White, 1983). If m is zero, R_e in Equation 2 is equal to R_0 in the identical Equation 1, which fit the observed data well. The good fits of Equation 1 in Figure 2

might be seen as support for Herrnstein's general approach, notwithstanding the problems of internal consistency. There are, however, several difficulties for this theory. First, it is usually assumed that R_e is constant over conditions. Here, extra-key reinforcement contributed to the total extraneous reinforcement, and this changed considerably over conditions. Because this variation occurred without apparently reducing the quality of the description provided by the hyperbolic function, it seems clear that empirically determined values for R_e are unreliable, and the good fits do not support Herrnstein's analysis at all. Second, if $m = 0$, then Equation 2 can no longer predict contrast, because R_e is constant and the only varying term in the denominator is multiplied by zero. Finally, the estimates for R_0 in Figure 2 are clearly too low, even considering the fact that they are estimated assuming constancy when in fact they varied. Because R_0 in Equation 1 equals $mR_e + R_e$ in Equation 2, these estimates should always exceed the rate of extraneous reinforcement obtained from the extra key, whatever the value for m in Equation 2. It may be noticed that estimated rates for R_0 in Figure 2 were lower than the obtained rates of alternative reinforcement from the extra key (Table 2) in 17 of 20 cases. This anomaly may be expected because k and R_0 are estimated from main-key data, and R_0 is therefore in units that are the same as those for main-key reinforcers (i.e., 3-s duration). Obtained extra-key reinforcers were often shorter than 3 s, which partly accounts for the low R_0 estimates from the curve fits (however, see White, McLean, & Aldiss, 1986).

Both the reallocation and direct interaction approaches are consistent with the matching law on which Herrnstein's (1970) and Williams and Wixted's (1986) models are based, but they differ in that the direct interaction theories attribute contrast to changes in rate of reinforcement in successively presented components (R_e in Equation 2) rather than to changes in concurrently available extraneous reinforcement (R_0 in Equation 1) as in reallocation theory. The fundamental issue is thus whether contrast is produced by successive interaction across components or by concurrent interaction within components. The present data seem to support the latter. However, changes in extraneous reinforcement in the constant multiple-schedule component were

themselves clearly related to reinforcer rate changes in the varied component; hence, reallocation may be viewed as a mechanism by which temporally separated components interact.

One issue that has received relatively little attention in statements of the reallocation hypothesis is the question of how reallocation may come about—whether as a result of behavior changes in the varied component or as a result of changes in the constant component. This is an important question because the answer determines whether or not the phenomenon of reallocation might serve as a plausible explanation for the phenomenon of contrast. There are at least two possible interpretations of reallocation. First, changes in available extraneous reinforcement during the constant component might indeed result from behavior change in the varied component and produce contrast effects through concurrent interaction with the constant component (i.e., with the main-key reinforcers in the present experiment). This would be consistent with the reallocation hypothesis. A second interpretation also exists, however—reallocation might be an epiphenomenon. It might be that changes to extraneous reinforcement in the constant component occur simply because of the feedback function that relates the rate of extraneous reinforcers obtained to the rate of alternative responses. Specifically, it has been suggested (McLean, 1988, 1991; McLean & White, 1983) that behavioral contrast in a constant component is best viewed as a change in the distribution of behavior between two response classes—responding on the multiple schedule for food reinforcers versus engaging in other behavior for extraneous reinforcers. Now assuming that the total behavior per component remains constant, this redistribution of behavior would result in complementary changes in *absolute* levels of the two types of behavior. In that case, positive behavioral contrast would necessarily be accompanied by a reduction in alternative responding during the constant component. Thus, a reduction in alternative responding would be a part of the phenomenon of positive behavioral contrast. Reduced alternative responding would bring about reductions in extraneous reinforcement in that component (reallocation), but it would be unacceptable then to suggest that the changes in rate of extraneous reinforcement explain

behavior change in that component. Instead, the reduction in alternative responding that brought about changes in extraneous reinforcement would represent a facet of contrast, one that still requires explanation in the same way as contrast in the multiple schedule requires it. In short, the issue is whether reallocation causes contrast or contrast causes reallocation.

Previous work cited in support of the reallocation hypothesis has been more susceptible than the present study to the question of whether reallocation causes or results from behavioral contrast. The major experimental evidence cited in support of the reallocation theory has been a study by Hinson and Staddon (1978), who arranged a running wheel concurrently with a multiple schedule of food reinforcement with rats as subjects. Over conditions, the value of one multiple-schedule component was reduced to extinction, while the other component was constant. It was found that the rats used the running wheel less in the constant component when it alternated with extinction than they did when both components arranged VI reinforcement. Moreover, contrast that occurred with the running wheel available was clearly greater than that observed in a series of conditions with the wheel unavailable.

The greater contrast with the running wheel present is consistent with expectations from the reallocation hypothesis (and with results from the present study), but Hinson and Staddon (1978) had not, as they claimed, demonstrated a possible mechanism for component interactions. First, reallocation of extraneous reinforcers was not demonstrated, because the reinforcers for running are merely inferred to have shifted between components when the second component was varied, and the inference can be drawn only from the change in rates of running. That is, Hinson and Staddon demonstrated reallocation of running behavior—not of the reinforcers for running. Moreover, if reinforcers for running are on a ratio schedule, as seems likely, then Hinson and Staddon's results admit the alternative interpretation that any reallocation of these reinforcers resulted from contrast, rather than causing it. Indeed, with explicit ratio schedules maintaining alternative behavior, extraneous reinforcer rate in the constant component is essentially independent of conditions in the al-

ternated component and can only depend on the other behavior in the constant component. Consequently, reallocation could be a significant contributor to contrast only by amplifying it—not actually producing it in the first place. It is not clear, therefore, whether the change in running in Hinson and Staddon's experiment represents a mechanism by which contrast occurs or is itself a part of the phenomenon of contrast.

The present study is less susceptible to questions about the origin of reallocation than is that of Hinson and Staddon (1978) because, except for one lean VR schedule sometimes in effect on the extra key (discussed shortly), alternative reinforcers were arranged by explicit VI schedules rather than by what were probably ratio schedules in Hinson and Staddon's study. Because of the nature of interval schedules, the feedback function relating extraneous reinforcement to alternative behavior was overall flatter than for ratio schedules, and changes in alternative reinforcement in a component will therefore depend less on rates of responding on the extra key in that component than would be the case if ratio schedules were used. Moreover, the use of VI schedules, and especially the use of a number of them simultaneously maintaining the same response, meant that the number of reinforcers available from the extra key in one component depended partly on extra-key responding during the previous component. For example, following a component in which extra-key responding was low, a number of the VI schedules operating on this key would have timed out, and at least as many of these reinforcers would then be available during the next component. Thus, behavior change in the varied component could bring about changes in reinforcement conditions during the alternated, constant component. By contrast, with ratio schedules the rate of extra-key reinforcement in a component would be virtually independent of extra-key responding in the previous component, and reallocation could then only be interpreted as epiphenomenal.

The question of the origin of reallocation can be addressed using two features of the data obtained in the present study, namely the absence of sufficient change in extra-key responding over conditions for the constant component and the effect of the constraint on reallocation. First, Figure 3 showed that over

the studied range of main-key reinforcer rates in the varied component, extra-key responding changed considerably in the varied component; consequently, large changes in extra-key reinforcers would be expected over conditions. By comparison, in the constant component extra-key responding did not vary much over conditions. Despite this near constancy of extra-key responding over conditions in the constant component, reallocation affected alternative reinforcement in that component quite markedly (Figure 1). There is some weak correspondence between changes in reinforcer rate and changes in response rate over conditions. However, it seems scarcely plausible that the approximate doubling of alternative reinforcer rate over conditions in Figure 1 could have resulted from the modest changes in extra-key responding in this component. Thus, even though one of the schedules on this key was a VR 425, the most likely interpretation is that constant-component alternative reinforcement changed from condition to condition as a function of varied-component extra-key responding (as the reallocation hypothesis requires), not constant-component behavior.

A second source of evidence against the epiphenomenal account of reallocation comes from the conditions in which reallocation was constrained by canceling reinforcers arranged but not obtained when components changed. If variations in constant-component alternative reinforcement resulted from behavior change during the same component (perhaps because of the lean VR schedule that contributed to the extra-key contingencies) and was not the result of behavior in the varied component, then similar changes would have been observed in the conditions regardless of the constraint on reallocation. Figure 1 showed quite clearly that this was not the case—canceling unobtained extra reinforcers at the end of components resulted in relatively invariant rates of alternative reinforcement over conditions in the constant component.

The present study thus demonstrates reallocation of extraneous reinforcers in conditions in which it is most unlikely to be an epiphenomenon of contrast. Accordingly, these data provide some indirect support for the reallocation hypothesis of contrast. However, the support they provide is limited because there are many remaining features of multiple-schedule data that seem to pose problems for

the theory (see, for discussion of these, Williams 1982, 1983). One of the main problems is Williams' (1979, 1981) finding that with pigeons as subjects, contrast in three- and four-component multiple schedules is mostly a function of reinforcement conditions in the following component, whereas the reallocation hypothesis given above focuses on conditions in the previous component. Williams has suggested that there may be more than one behavioral process producing contrast (e.g., Williams, 1988, 1990; Williams & Wixted, 1986)—one involving the following component and producing behavioral contrast and another involving the previous component and producing local or transient contrast. Reallocation could reasonably account only for the local contrast because it relies on behavior change in the previous component. In sharp contrast to this view, McLean and White (1983) and McLean (1988) concluded from studies of multiple concurrent schedules that behavioral contrast could not reasonably be explained in terms of direct interaction; therefore, they favored the reallocation hypothesis. McLean (1991) showed that for local contrast, direct interaction was supported and reallocation need not be invoked. Clearly, we are some way from a resolution of these issues, but whatever the final status of reallocation as a contributor to contrast, it is clearly a robust phenomenon in conditions that assure us that it is not a facet of contrast itself. More needs to be known about it.

To conclude, the present study has shown that in conditions in which extraneous reinforcers can be reallocated between multiple-schedule components, the amount of extraneous reinforcement available during the constant component depends on the amount of other behavior during the varied component. This is a necessary requirement for an account of contrast in terms of reallocation of extraneous reinforcers. Moreover, contrast was reduced or eliminated when extraneous reinforcement was made independent of behavior in the previous component by canceling accumulated reinforcers at the end of components. As is well known and as is predicted by the matching law, the frequency of one response of a concurrent pair depends in part on reinforcement for its concurrent alternative (e.g., Catania, 1963; Rachlin & Baum, 1972), so that variation of reinforcement in a multi-

ple-schedule component is likely to produce changes in alternative behavior during the same component. For example, reducing one component to extinction increases these alternative responses. What the present work has done is to reveal the influence of this change in "other" behavior over the alternative reinforcement available during the alternated, constant component. The effect was a decrease in extraneous reinforcers for the constant component. This, in turn, decreased competition between extraneous and multiple-schedule reinforcers during the constant component, and concurrent interaction might well contribute to the increased responding known as positive behavioral contrast.

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